

HOT APPLIED COAL TAR COATINGS

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INTRODUCTION

The very high aromaticity of high temperature coal-tar pitch accounts for many of its unusual physical and chemical properties which make it the preferred raw material for a wide variety of applications. High temperature coal-tar pitch is practically inert to the action of water and neither absorbs or transmits it. High-temperature coal-tar pitch is highly resistant to attack by bacteria and fungi. This property, together with its moisture resistance, make it eminently suitable for roofing; waterproofing; coating of buried steel pipe lines to protect them from corrosion action of wet soil; lining of water pipes, tanks, etc.

COAL-TAR PITCH BASE FOR ENAMELS

Normal coal-tar pitch is somewhat sensitive to changes in temperature. It is comparatively hard and brittle at low temperatures and it tends to soften and flow at high temperatures. It exhibits simple Newtonian flow and is subject to cold flow, i.e., it is deformed by the continued action of a small applied force and in direct proportion to the amount of force applied.

In the early 1930's, a means was found to reduce the susceptibility of coal-tar pitch to temperature change. A "plasticized" pitch was produced by digestion of bituminous coal in coal tar and high boiling coal-tar distillate oils. These plasticized pitches show much reduced susceptibility to temperature changes. They are comparatively soft and are not brittle at low temperatures, and at the same time, they do not soften too readily and flow at high temperatures. In rheological terms, they exhibit complex flow. They can be deformed by the action of strong forces but are to some degree rubbery and resilient and they are very little affected by the action of small forces of the order of 2 to 5 psi which are the estimated order of soil distortion forces at work on a buried, shielded pipe coating. (1)

Figure 1 and Figure 2 summarize pressure deformation tests made by Allied Chemical. These tests were made by immersion of an apparatus, in constant temperature water baths maintained at 77°F and 115°F, in which a weighted $\frac{1}{4}$ " diameter blunt monel metal rod rests on a flat dish filled with enamel. These tests show that despite the apparent softness of the plasticized enamel it is more resistant to the action of deforming forces in the low stress range. The tests at 77°F, which can be related to normal temperature conditions of soil forces on buried pipe, show less deformation for the plasticized enamel in the 2 to 5 psi range. The tests at 115°F can be related to deforming forces in handling coated pipe in hot weather or to soil forces on buried pipe in hot line service. The plasticized enamel shows far superior resistance to deformation when deforming forces are comparative light.

HISTORY

Coal-tar coatings have been used for over 100 years to protect ferrous metals against underground corrosion. In 1913, an early form of coal-tar enamel was used in protecting the gates, locks and penstocks of the Panama Canal. Examination after 35 years of service showed them to be in perfect condition. The first application of coal-tar enamel to steel pipe for potable water was made in New York in 1914. At the last count this line was still in operation after over 45 years of service. In the 1930's, AWWA type enamels were used extensively in water lines in many large scale projects particularly in the Far West. These installations are still giving trouble-free service and the coal-tar enamels are virtually unchanged after service of over 30 years. Many excellent general articles have been presented on coal tar enamels. (2,3,4,5,6,7)

MINERAL FILLERS

In the production of coal-tar enamels, usually around 25 to 30% of inert, fine mineral fillers are added to the pitch to improve mechanical strength such as resistance to impact and resistance to deformation from soil forces. Fillers also help to reduce flow at high temperature and tendency to crack at low temperatures.

SPECIFICATIONS

Typical specifications for various grades of coal tar enamels are shown in Table 1. These enamels differ chiefly in the variations in atmospheric or service temperature ranges they will withstand--either from cracking at low temperatures or flow at deformation at high temperatures.

Unplasticized Enamel: A narrow range enamel - exposure range is 30 to 120°F. This grade of enamel is hard and highly resistant to deformation from soil forces. It also has very high resistance to moisture and soil chemicals. It is easy to heat and apply, and is best suited for "over the ditch" application where it will not be subjected to extremes in atmospheric temperatures in storing or rough handling in shipping.

Partially Plasticized: A modified grade to better withstand variations in temperatures. Exposure range is 0 to 140°F. It is a good all-purpose enamel. It is easy to apply and is suitable for either shop coating or over the ditch application.

SPECIFICATIONS

Plasticized Enamels:
Regular Grade

A fully plasticized enamel with a wide exposure range of -20 to 160°F. It is resistant to shock and deformation and is less subject to damage in handling. With wide exposure range, it can be stored for long periods without damage to coating from extremes in temperatures.

AWWA Grade:

A fully plasticized enamel with a wide range of -20 to 160°F. It is softer than Regular Grade and is more flexible and better suited for large diameter pipe. It is specifically designed to meet exacting requirements of AWWA. It also finds application on gas and product lines where very low temperatures might be encountered in storage of coated pipe.

Hotline Grade:

A fully plasticized enamel but higher in softening point and harder so as to better withstand high temperature service. Exposure range is 0 to 180°F. It is designed and recommended for:

1. Gas pipelines, at the discharge side of pumping stations where gas enters the pipe at temperatures above 120°F.
2. Warm swampy areas, salt flats, desert beds and other places where excessive soil stress is present.
3. Areas where backfill and trenches are rough, full of stones and other objects which normally penetrate softer coatings.
4. Hot oil lines and lines encapsulating electric cables where temperatures are consistently high most of the time, but do not exceed 180°F or 200°F for short term exposure.

P R I M E R S

Primers for the enamels must be capable of application by spraying, rolling, or brushing. They must dry in a reasonable period of time and they must give a strong bond with the enamel.

Usually the primers consist of a pitch base, similar to that used in making the enamel, cut back with an aromatic solvent.

There are available quick-drying primers that in addition to developing a strong bond, have the added advantage of very quick-drying properties. These quick-drying primers are chemical as well as conventional coal-tar pitch based primers.

REINFORCEMENT AND OUTER WRAP

It is general coating practice to pull a glass mat into the hot enamel as a reinforcement and the outer side of the coating is protected with a tar saturated asbestos felt.

The glass mat is composed of light weight glass fibers randomly oriented. The sheet is very open and is easily pulled into the hot enamel. This mat acts as a reinforcement for the enamel coating and helps to resist cracking in handling.

The tar saturated asbestos felt outer wrap can be a standard weight of approximately 15 lbs. per 100 sq. ft. or a light weight at 9.0 lbs. per 100 sq. ft. The standard weight has a higher tensile strength than the light weight and is the preferred type. As an added strengthening agent glass fiber can be imbedded into the asbestos felt at spaced intervals (usually $\frac{1}{4}$ ") across the sheet. The asbestos felt outer wrap is intended to minimize damage when handling the coal-tar coated pipe as well as to protect it from damage during the back filling operation and from soil forces in service.

A Kraft Wrapper is usually applied as a finishing protective cover.

A P P L I C A T I O N

Coal tar enamel coatings are both mill and field applied. Specifications for enamel coatings systems from simple single enamel coat to multiple enamel coats with glass reinforcement and asbestos shields are shown in Table 2. The severity of service conditions determines the system to be used.

M I L L A P P L I C A T I O N

This application may include interior lining in addition to the exterior coating and wrapping.

The pipe is sand or grit blasted to remove excess rust and mill scale and a coating of primer is applied.

Usually in applying the enamel the pipe moves thru the coating equipment with a rotating motion and the hot enamel is flowed onto the pipe. It is also general practice to pull a glass wrap into the coating as well as to apply an outer protective wrap when applying the hot enamel.

Interior linings for water lines are centrifugally^{applied by} flowing hot enamel into the pipe while it is rotating at a speed of about 900 lineal ft. per minute.

FIELD APPLICATION

In Field Application, the coating is applied with specialized equipment that rides on the pipe. The pipe is brought to the right of way and "strung" in place; the welders then weld the pipe sections together; the cleaning unit consisting of rotating wire brushes removes mill scale and rust just prior to application of the primer. Following the primer unit is a similar unit where the hot melted coating is applied to the pipe with a glass wrap and a protective outer wrap is applied with the same equipment. The protected pipe is then installed by lowering into the ditch.

MOISTURE ABSORPTION

Minimum moisture absorption is the most important single property that a good coating must have. Minimum moisture absorption goes along with high electrical resistivity. If a coating does not absorb water, it does not become electrically conductive; and therefore, cost of current to protect the pipe cathodically is reasonably low. Minimum moisture absorption is necessary in order to have a continuous strong bond. If a coating absorbs water, and this water gets to the interface between enamel and primer, the bond is destroyed. Minimum moisture absorption is also tiedⁱⁿ with resistance to soil chemicals. These soil chemicals are water-borne and will never do any damage unless they penetrate the coating, and this will only be the type of coating which

will absorb water.

Water absorption of coal-tar enamels is extremely low. NACE Committee T-6A on Thermoplastic Coal Tar Base Linings reports that after 6 years immersion, coal-tar enamels, at approximately 100 mils thickness, show an absorption of only 1.7 to 2.3 gms. per square foot or 0.5 to 0.6% by weight.

Water absorption tests at Allied Chemical for a 2-year immersion period show 1.4 gms. per sq. ft. for unplasticized enamel and 3.0 gms. for plasticized enamel. Test results are shown in Figure 3. It will be noted that the absorption curve is levelling out as the time of the test progresses. These tests were made using 316 stainless steel plates which were coated by dipping in hot enamel.

High moisture absorption in time results in the coating becoming electrically conductive, giving rise to high current consumption and high cost for cathodic protection. This high moisture absorption in time results in complete chemical degradation. The high moisture absorption also results in complete loss of bond to the pipe.

Dr. J. O. Harris of Kansas State University determined actual water content by the Dean Stark Method on samples of coal-tar and asphalt enamels removed from active buried pipe lines after up to 29 years service. (9) Analyses of a chart presented in Dr. Harris' paper shows that for 28 coal-tar enamels in the test, service varied from 3 to 29 years with an average of 14.1 years service. The maximum moisture content of all coal-tar enamels was 0.3%. The 19 asphalt enamels in the test varied from 7 to 26 years in service with an average of 13.7 years. The moisture content of the asphalt enamels varied from 3 to 19% with an average of 12.4%.

Dr. Harris' work clearly shows the necessity for long-term water absorption tests for reliable evaluation of pipe coatings.

ELECTRICAL RESISTANCE

High electrical resistance is necessary in the coating so that there will be a minimum amount of current required for cathodic protection. Furthermore, this high electrical resistance must be not only high initially, but must remain high through years of service. Most corrosion engineers and pipeline operators feel that a good coating tested when it is first installed in the ground should test from $\frac{1}{2}$ to 2 megohms per square foot. A generous allowance is made here for some loss of resistivity due to damage in handling prior to laying the pipe, moisture absorption in storage prior to burial, and to damage from burial operations and backfilling. In an excellent article, the IEEE Guide for Selecting Coatings for Pipes of Pipe-Type Cable Systems (10) a comparison is made of bituminous coatings for pipe cable systems. Reinforced Coal-Tar Enamel, Hot-Line Grade, is rated at 1 megohm per square foot when installed and still 1 megohm after 5 years in wet soil. Reinforced asphalt enamel is rated at 1 megohm when installed and 0.1 megohm after 5 years in wet soil. Asphalt mastic is rated at 10 megohm when installed but 0.1 megohm after 5 years in wet soil. In terms of current requirements

for cathodic protection--this would mean that for a mile of 8" pipe, 3 milliamps would be required initially and after 5 years of service, coal tar coated pipe would still require only the same current. The asphalt coatings would require 30 milliamps after 5 years service. (10, 11, 12).

In our own laboratory work, specimens of coated steel are very carefully prepared and are of the proper and specified film thickness. There are no thin spots where felts or glass cut into the coating, no damage from handling or installation in the ground, and true resistivity of the coating itself are determined. In this type of test, initial resistivities are consequently far higher than are obtained in a commercial pipe installation.

Two series of tests were run in Allied's laboratories. In the first series a number of enamels were tested at approximately $3/32$ of an inch thickness of coating. The enamels were immersed for one year in N/10 Sodium Chloride solution. Initially all enamels tested well over 1,000 megohms per square foot. Results on coal-tar enamel show very high electrical resistance after the one year immersion period. Test results are shown in Table 3.

In another series of tests in which coal-tar enamels of $2/32$ of an inch thickness were subjected to 10 years of continuous immersion in a 5% sodium chloride solution, resistivity was more than 50 megohms per square foot.

Since the resistivity of coal-tar enamels is extremely high, and remains at this high value if the coating is not distorted or damaged, it is the imperfections in the coating and the resistivity of the soil water contained in these imperfections that control the magnitude of the coating resistance that will be measured in the field.

CONTINUOUS STRONG BOND

This is a corollary of the chemical inertness of coal tar pitch. Coal tar pitch shows extremely low moisture absorption, is highly resistant to bacterial deterioration, and highly resistant to soil chemicals. As a result, the coating remains practically unchanged through years of service. No moisture can get through the coating to the pipe and the bond remains firm and strong throughout long years of burial. Coal tar coated pipelines have been dug up after being in service for 20-30 years and more and we find the coating unchanged and the bond strong. The coal tar coating must be laboriously removed and chipped off with a hammer and scrappers.

A Southern Natural Gas line recently dug up and cleaned at the Harvey, Louisiana, yard of the Shamrock Pipe Coating Company is a typical example of coal tar coating which was practically unchanged after 35 years burial. When the enamel was chipped off this pipe, the perfect bond was shown by the fact that, when the coating was removed, the original mill markings on the steel pipe were clearly shown.

RESISTANCE TO SOIL CHEMICALS

Coal tar pitch is almost completely inert to moisture and soil chemicals. Coal tar coatings and coal tar pitch used as pipe coatings and for waterproofing have been dug up after 20-30 and 50 years of service underground. They were found to be practically unchanged. Coal tar pitch does not absorb any appreciable water and is not affected to any appreciable extent by soil bacteria.

The chemical stability of coal tar pitch is due to its aromatic character. The molecular unit of aromatic compounds is the benzene ring. It is a chemical structure of great strength and stability. In the symmetrical benzene ring, three single bonds and three double bonds resonate between the carbon atoms. These structures are called "aromatic rings", and the powerful inter-atomic forces holding them together account for the high stability of coal tar compounds. In the original formation of coal these benzene rings were chemicals united to make large, complex aromatic molecules. In the aromatic molecules comprising coal tar, the chemically inert carbon atoms outnumber hydrogen atoms two to one. It is the high aromatic content of coal tar - over 90% - that gives it great strength and resistance to attack by water or oxygen. Aromatic compounds, as a class of chemicals, have a markedly lower degree of water solubility and affinity for water than aliphatic compounds.

RESISTANCE TO SOLVENT ACTION

Coal tar enamels are substantially insoluble in petroleum products. For oil product lines, this is an important property. In the event of a leak in an oil line, the insolubility of the coal tar enamel coating will assure minimum damage to the coated pipe. This also applies to any pipeline or coated underground steel structure that is in contact with soil contaminated with petroleum products. A nearby foreign pipeline carrying crude or refined petroleum products can contaminate soil near a well-coated line.

RESISTANCE TO SOIL STRESS AND MECHANICAL DAMAGE

Pipe coatings must withstand a reasonable amount of mechanical abuse. If the proper grade of coal tar enamel is used for the conditions to which it must be exposed both prior to burial and after burial; and if it is used in accordance with manufacturer's instructions; and if it is used along with recommended shielding and also reinforcing where it is so specified; then coal tar enamels will not be distorted or damaged and the original coating thickness will be maintained, and the good service expected of a coal tar coating will be obtained.

RESISTANCE TO BACTERIA

Bacteria can feed on many hydrocarbon materials, but coal-tar coatings show no utilization by bacteria. Coal-tar enamel is inert to fungus attack. (13, 14).

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SPECIFICATIONS

TABLE 1

TESTS	METHOD	UN-	PARTIALLY	PLASTICIZED		
		PLASTICIZED	PLASTICIZED	Regular	AWWA	Hotline
Softening Point, R & B, F.	ASTM D 36	185 - 195	195 - 205	220 - 230	220 min.	250 min.
Penetration: 77 F-100 gms-5 sec 115 F-50 gms-5 sec	ASTM D 5	0 - 2 1 - 8	2 - 7 10 - 25	5 - 10 15 - 25	10 - 20 15 - 55	0 - 5 5 - 15
Filler (ash) %	ASTM D 271	22 - 32	22 - 32	22 - 32	25 - 35	22 - 32
Specific Gravity, 77F	ASTM D 71	140 - 160	140 - 160	140 - 160	140 - 160	140 - 160
PERFORMANCE TESTS						
High Temperature (1/16" max sag)	AWWA C 203	5 hrs @ 120 F	5 hrs @ 140 F	24 hrs @ 160 F	24 hrs @ 160 F	5 hrs @ 180 F
Low Temperature (no cracks)	AWWA C 203	5 hrs @ 30 F	5 hrs @ 0 F	6 hrs @ -20 F	6 hrs @ -20 F	6 hrs @ 0 F
Peel Test (no peel)	AWWA C 203	80 - 120 F	80 - 140 F	80 - 160 F	80 - 160 F	80 - 180 F
Spark Test 10,000 volts, low amperage, 2/32" coating tkns.	AWWA C 203	no sparks	no sparks	no sparks	no sparks	no sparks
Application Temp. (approx.) F.		400	450	475	475	500

TABLE 2

SYSTEMS	SHOT BLAST PRIMER 3/32" MIN ENAMEL GLASS WRAP 15 # ASBESTOS FELT 2/32" ENAMEL GLASS WRAP 15 # ASBESTOS FELT SEAL COAT OF ENAMEL 60 # KRAFT PAPER ELECTRICAL INSPECTION										SERVICE
Single Coat Single Wrap	●	●	●	●					●	●	Normal Underground Environment
Single Coat Single Wrap	●	●	●	●					●	●	Normal Underground Environment
Single Coat Double Wrap	●	●	●	●	●				●	●	Normal Underground Environment
Double Coat Double Wrap	●	●	●	●		●	●		●	●	Severe Underground Environment - rocky terrain, corrosive soils, submarine lines, etc.
Double Coat Triple Wrap	●	●	●	●		●	●	●	●	●	Severest Corrosive Environment, such as river crossings, etc.

ELECTRICAL RESISTIVITY OF SPECIMENS OF ENAMELS

TABLE 3

immersed in N/10 Sodium Chloride
solution · Wheatstone Bridge, 100 V.

ENAMEL	RESISTIVITY IN MEGOHMS/SQ. FT.	
	30 DAYS	1 YEAR
Av. of 5 Asphalt Enamels	82,000	less than 0.6
Un-plasticized Coal Tar	200,000	over 200,000
Partially Plasticized Coal Tar	20,000	2,100
Plasticized Coal Tar, Regular Grade	6,000	1,300
Plasticized Coal Tar, Hotline Grade	8,000	1,900
Plasticized Coal Tar, AWWA Grade	1,600	300

FIGURE 1

RHEOLOGICAL DIAGRAM FROM BLUNT ROD PRESSURE DEFORMATION

*Test Values
at 77°F*

Rate of Deformation
0.1 MM per Day

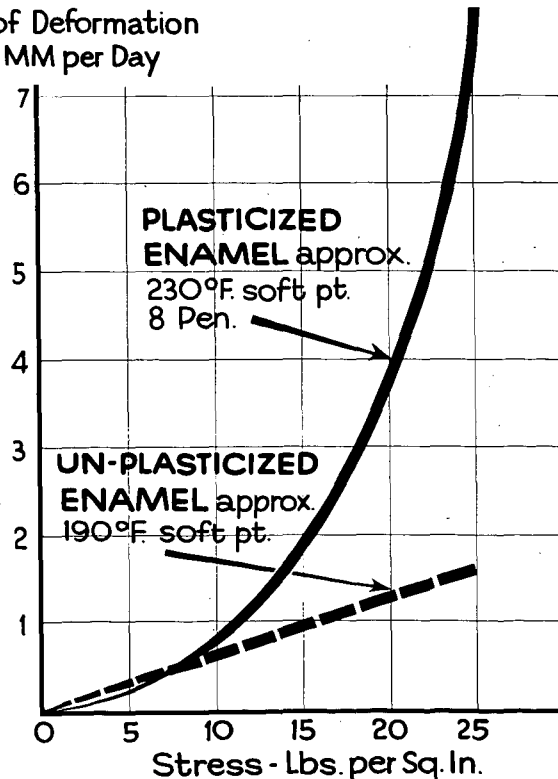


FIGURE 2

RHEOLOGICAL DIAGRAM FROM BLUNT ROD PRESSURE DEFORMATION

Test Values
at 115°F

Rate of Deformation
0.1 MM. per Hr.

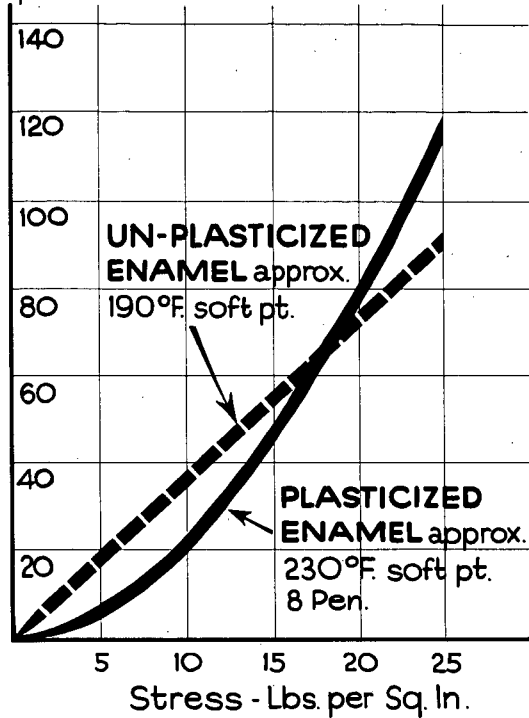


FIGURE 3

WATER ABSORPTION COAL-TAR ENAMELS

Absorption
GMS per sq. ft.

